

Jet Propulsion Laboratory
California Institute of Technology

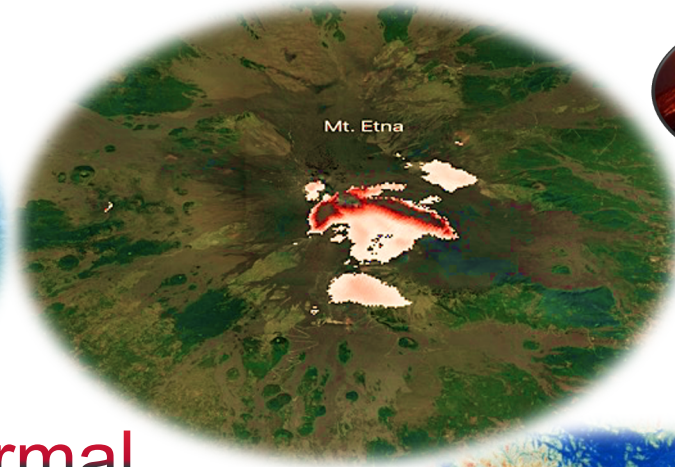
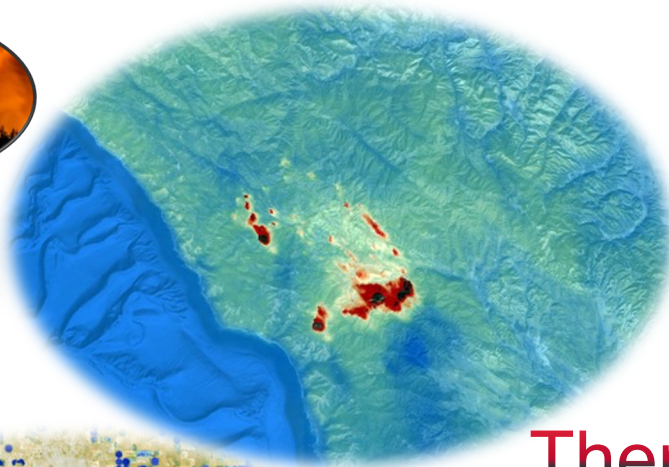
Applications of thermal infrared imagery in the study of Earth's ecosystems

Kerry Cawse-Nicholson, Simon Hook, Christine Lee, Glynn Hulley, Gregory Halverson, Dana Freeborn, Gerardo Rivera, and the ECOSTRESS Team

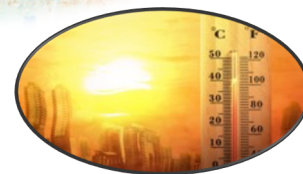
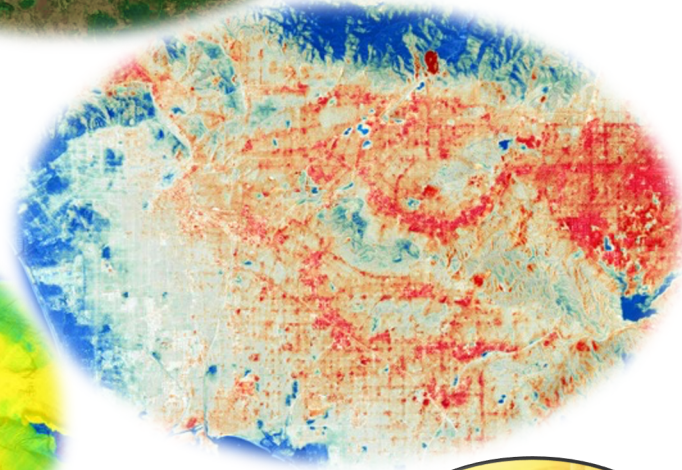
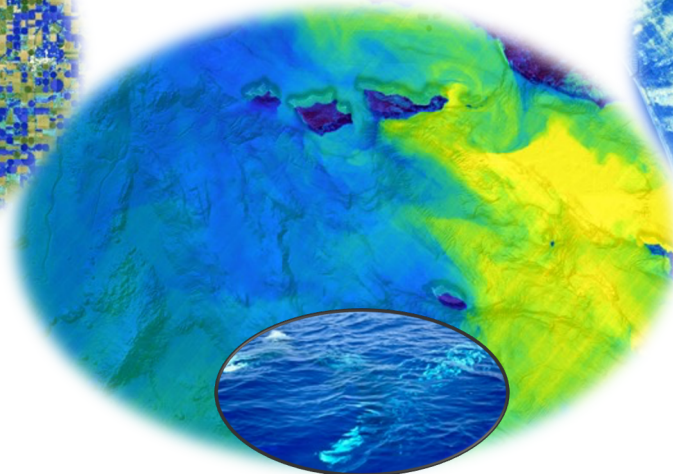
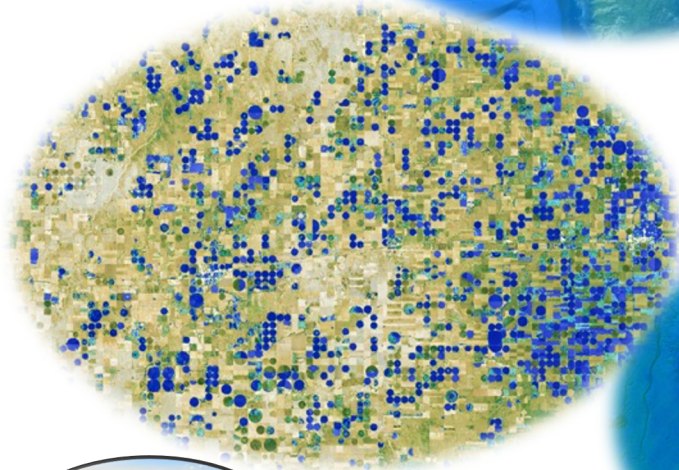
Jet Propulsion Laboratory, California Institute of Technology

Credit: NASA





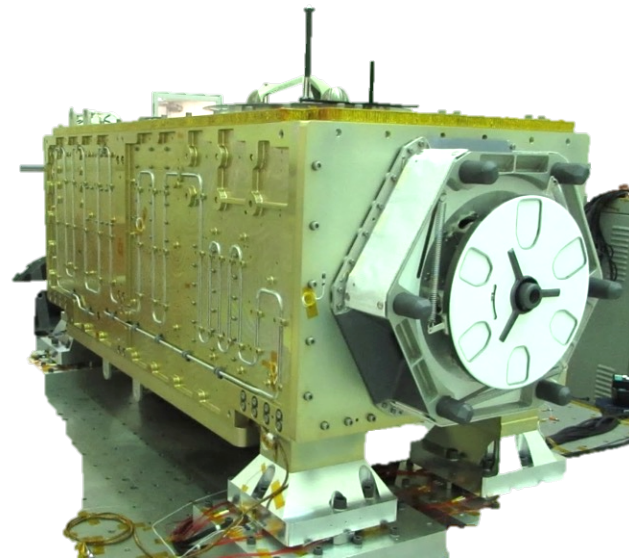
Thermal Infrared





Instrument Specifications

Description	Value	Units	Notes
Spectral bands acquired	6		3 bands currently downloaded (Apr 2021)
Band centers	Band 1 - 8.29, *Band 2 - 8.78, Band 3 - 9.20, *Band 4 - 10.49, *Band 5 - 12.09	μm	*After May 15, 2019, only these bands are downloaded
Pixel size at nadir	69 x 38	m	Products available at 70m
Swath width	384	m	Varies with ISS height, assumes height of 400 km
Radiometric accuracy at 300K	0.5	K	Values vary by wavelength



ECOSTRESS

Maximizing Earth's Precious Resources

The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) will measure the temperature of plants and use that information to better understand how plants respond to heat and water stress. This stress is detectable from space at the scale of an individual farmer's field, and we can use this information to manage water resources and monitor droughts. Evapotranspiration (ET) derived from ECOSTRESS can infer plant stress before any physical degradation is observed with the naked eye.



**How do plants
respond to
changing water
availability?**



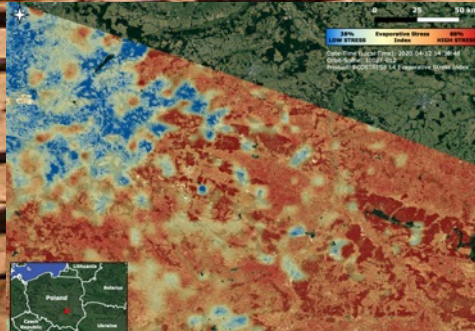
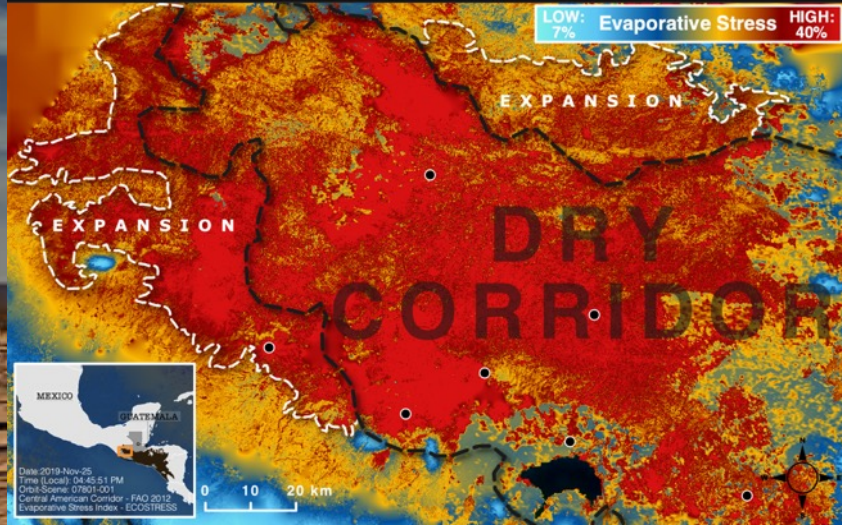
**How do changes in
evapotranspiration (ET)
throughout the day
affect vegetation growth?**



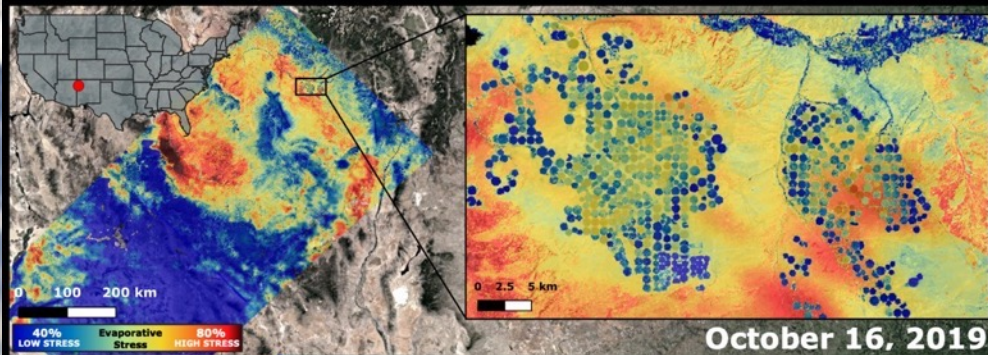
**Can we use ET
measurements to
optimize agricultural
water use?**

Drought around the World

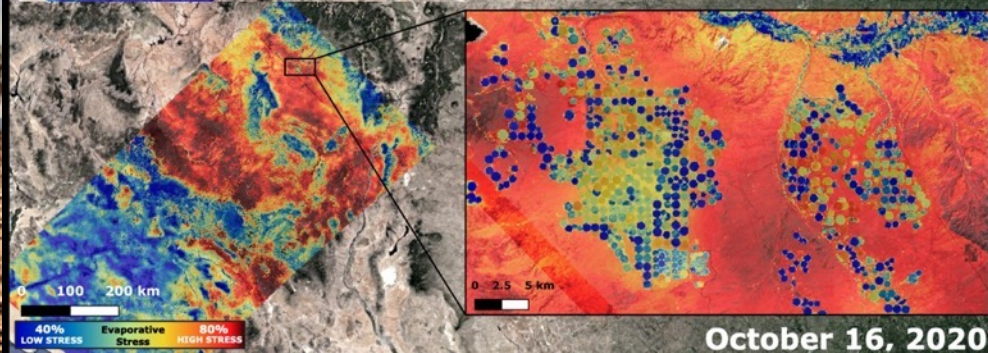
The Expansion of the Central American Dry Corridor as seen by ECOSTRESS



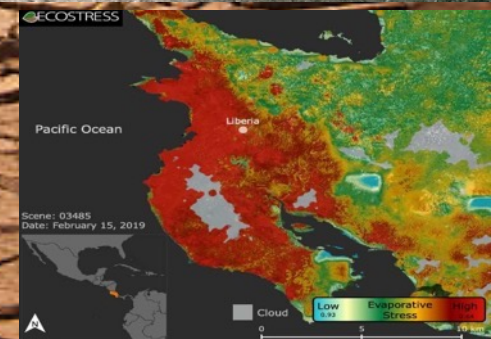
Change in Drought from October 2019 to 2020 as captured by ECOSTRESS



October 16, 2019



October 16, 2020



Understanding Diurnal Cycles of Plant Water Use and Carbon Uptake with Existing and New Products Based on ECOSTRESS, MODIS, and FLUXNET (PI: J. Xiao; University of New Hampshire)

- ECOSTRESS allows us to assess how plants use water and absorb carbon over the course of the diurnal cycle.
- e.g., ET images acquired in the early morning and afternoon indicate that some agricultural fields (likely irrigated) show much more ET while some fields are drying out (with plants under water stress) in the afternoon. This has never been possible in the history of remote sensing before ECOSTRESS. (*left panel*)
- e.g., ECOSTRESS allows us to generate GPP (total biomass fixed by the vegetation in a unit area within a unit time) estimates with 70m resolution for different times of day and to assess how plant photosynthesis varies throughout the day (*right panel*)

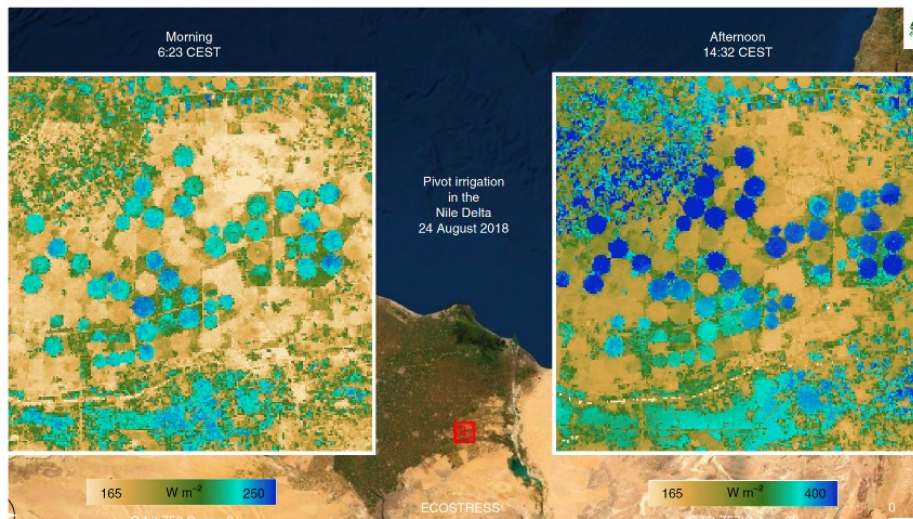


Fig. 2 | ECOSTRESS images from the Nile Delta within the same day. NASA's ECOSTRESS captured changes in ET from agricultural fields of the Nile Delta, Egypt, from the ISS in the morning and afternoon on 24 August 2018. The image on the left is from 6:23 central European summer time (CEST) and the image on the right is from 14:32 CEST. There are larger differences in ET between the agricultural fields in the afternoon than in the morning. Some fields show much more ET while some fields are drying out in the afternoon. The geographical coordinates of the centre of the ECOSTRESS images Orbit 752, Scene 2 (left) and Orbit 757, Scene 26 (right) are 30.54° N and 31.85° E, respectively. The scale bar applies to the background map; the pixel size of the inset maps is 70 m.

Xiao et al., Nature Plants, 2021

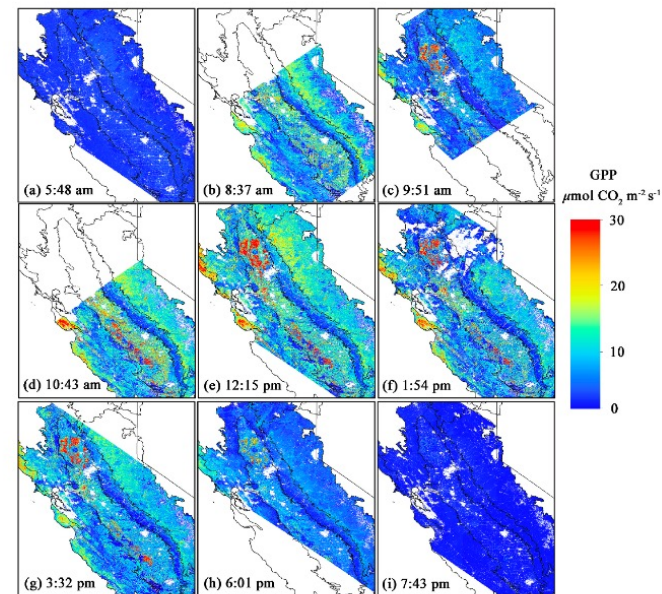


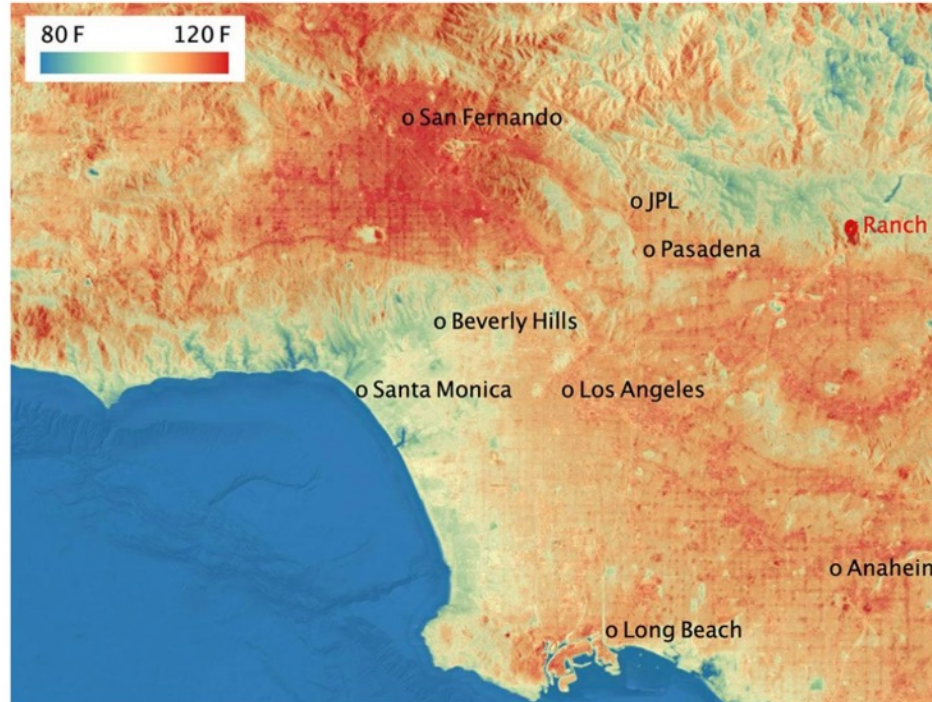
Fig. 5. Magnitude and spatial patterns of predicted ECOSTRESS GPP at different times of day in summer 2019 across the Central Foothills and Coastal Mountains, Central Valley, Sierra Nevada and Coast Range in California.

Li, Xiao, et al., RSE, 2021

California's Intense Record-Breaking Heat Wave Monitored From NASA's ECOSTRESS

TOPICS: JPL NASA Weather

By JET PROPULSION LABORATORY AUGUST 21, 2020

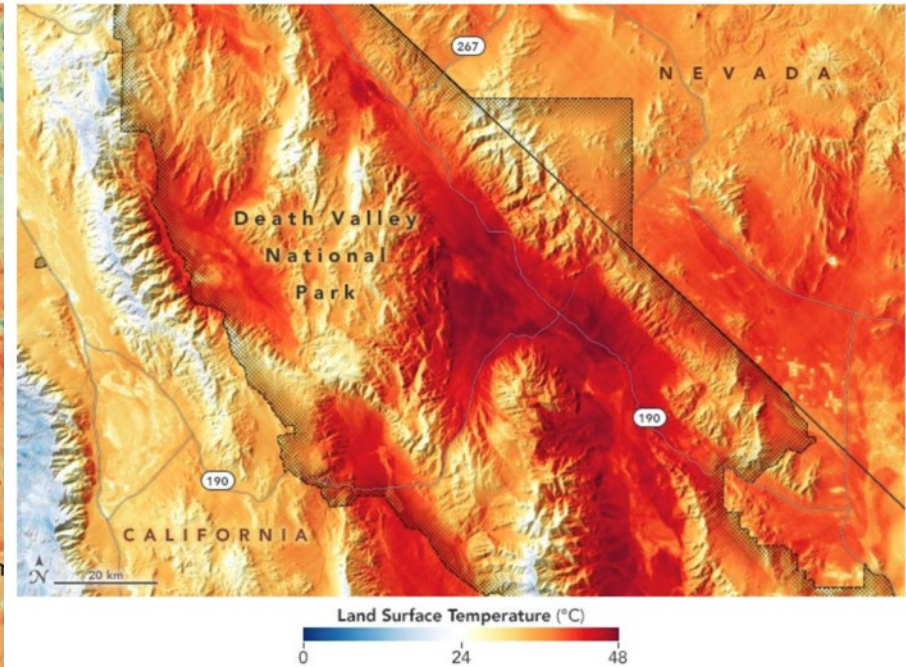


This ECOSTRESS temperature map shows the land surface temperatures throughout Los Angeles County on August 14, 2020, during a heat wave. Credit: NASA/JPL-Caltech

Extreme Heat in Death Valley Monitored by ECOSTRESS on Space Station

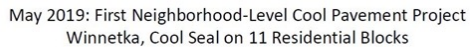
TOPICS: Earth Observatory Environment NASA Weather

By MICHAEL CARLOWICZ, NASA EARTH OBSERVATORY AUGUST 21, 2020



August 16, 2020. (Click image for high-resolution view.)

(G. Hulley, JPL)

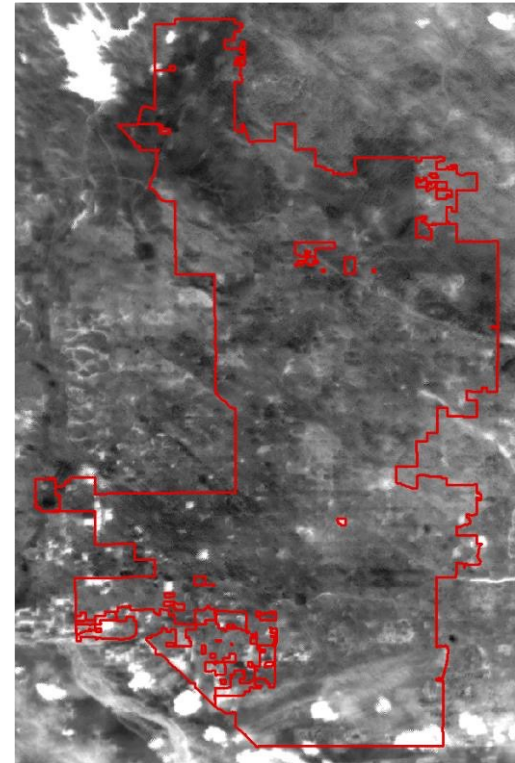


ECOSTRESS Project Title: Changing landscapes, UHI and the effects on city water conservation policy

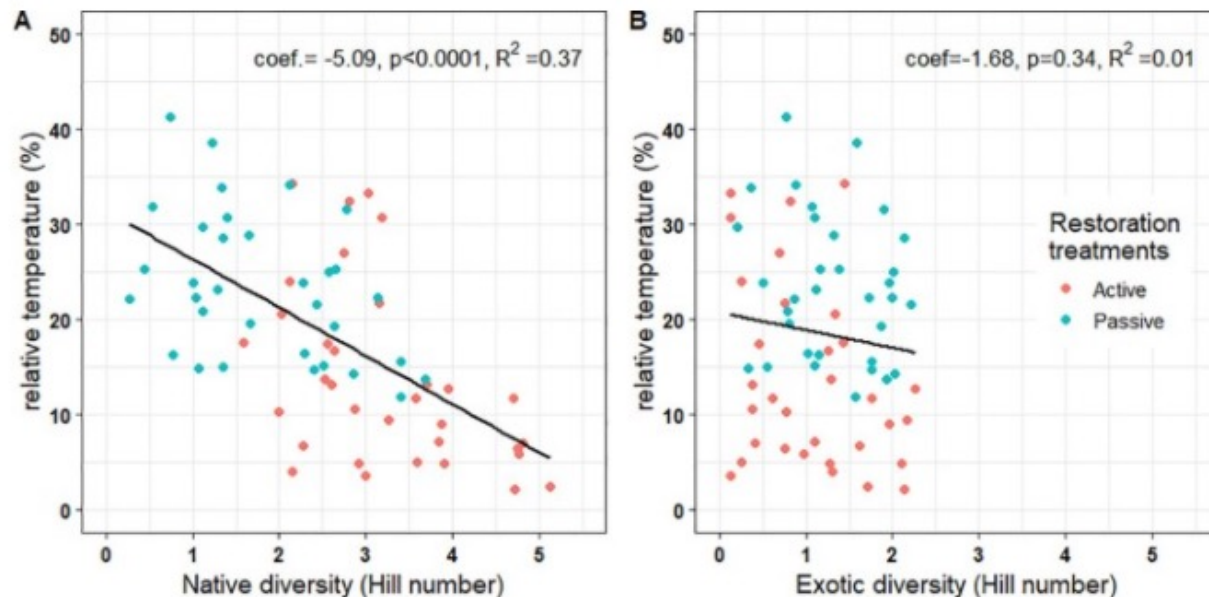
(PI: S. Myint, S. Arizona State University)

- Household property values and median household income have negative correlation with LST (lower income => higher LST)
- A positive correlation is observed between percentage of household below poverty level and LST (environmental inequity)
- American Indian and Alaska Native alone (AA) and Black or African American alone (BL), have a consistently positive relationship with LST (experience stronger urban heat effects)
- Hispanic or Latino (HI) was positively correlated with LST consistently. Conversely, Non-Hispanic (NH) has a negative relationship (more Hispanic => higher LST)
- On the contrary, the races of Asian alone (AS) and White alone (WH) presented a consistently negative relationship with LST.
- Diversity Index (DI) is positively correlated with LST
(More diverse communities experience higher heat effects)

ECOSTRESS LST (Phoenix)



ECOSTRESS diurnal temperature patterns are related to biodiversity (J. Hamburg)



Experiment: 31 fields restored from agriculture to oak woodland between 2006 and 2013.

Result: Decrease in temperature of 1.5 percentage point per year since restoration

Impact: Our results offer compelling evidence that relative temperature has potential to be used as an indicator to measure ecosystem change resulting from restoration.



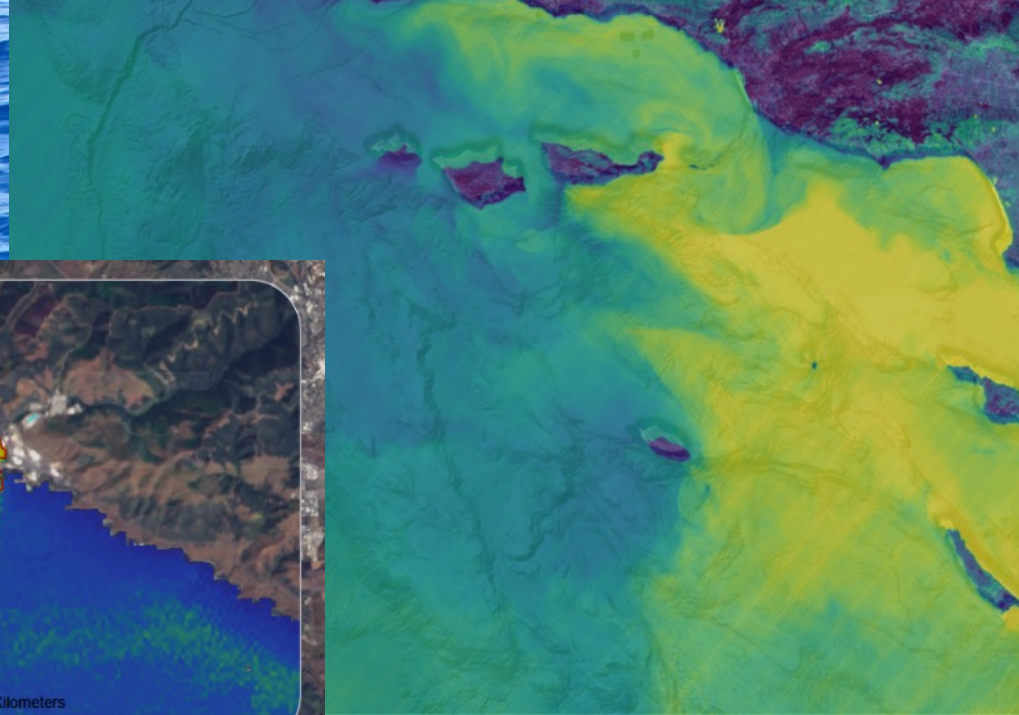
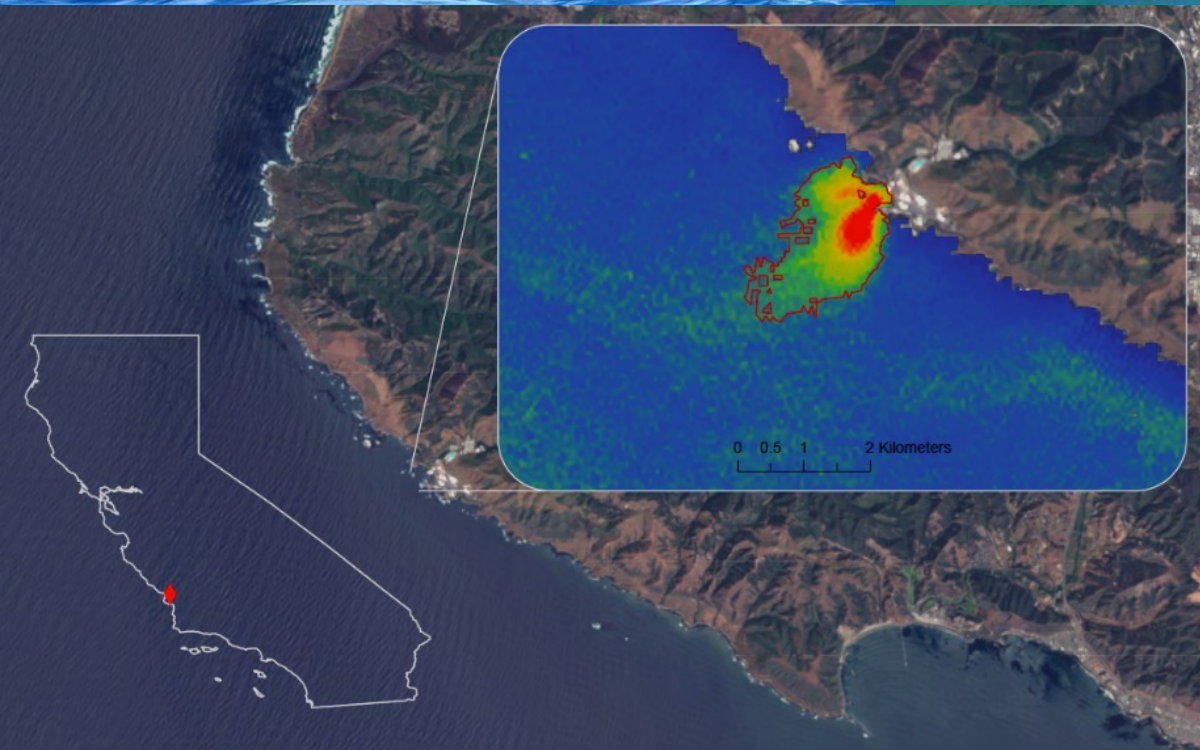
Ecological Indicators
Volume 113, June 2020, 106249



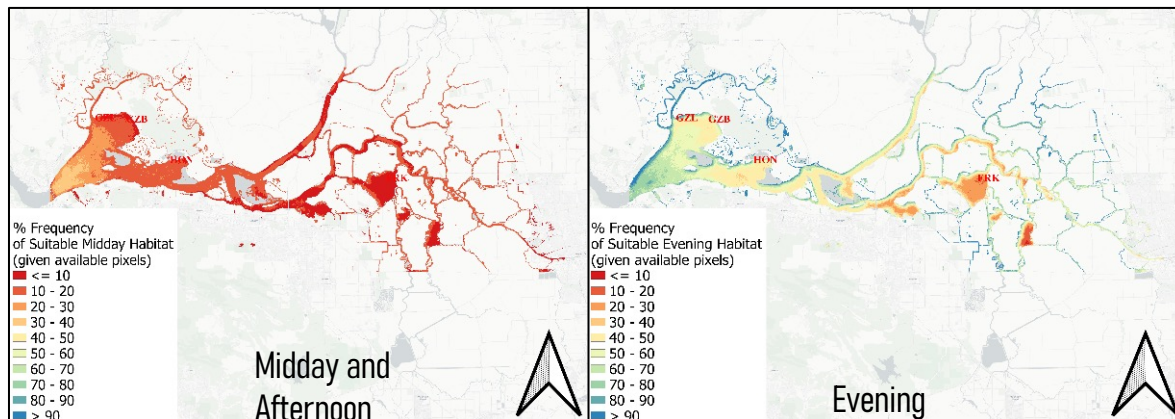
Surface temperature as an indicator of plant species diversity and restoration in oak woodland

L. Jonas Hamburg ^a, Roydon A. Fraser ^b, Derek T. Robinson ^c, Andrew J. Trant ^a, Stephen D. Murphy ^a

Ocean currents and plumes



Water temperature impacts endangered fish in California's water supplies (PI: C. Lee, JPL)



Credit: Rebecca Gustine / WSU

Temperature conditions in the Delta exceed lethal conditions in the afternoons during the summer, something only resolvable at these scales with ECOSTRESS

Background: Water in Central Valley and Southern California is conveyed through the Sacramento-San Joaquin Delta, which is an inverted Delta and highly fragile ecosystem. Stakeholders in the region are committed to maintaining this critical water supply in a way that also manages the ecosystem to protect this sensitive species there. The Delta smelt are a highly impacted species, and this study evaluates their habitat suitability in terms of thermal conditions and their thermal tolerance.

Results: Water temperature is considered the most important variable governing habitat suitability and is typically measured through discrete measurements (fixed stations, cruises). Analysis of ECOSTRESS observations shows that thermal habitat suitability for the endangered Delta smelt, is severely degraded in summer afternoons (most of Delta is <20% habitable), compared with other times of day. This would not have been possible at this level of detail without ECOSTRESS.

Significance: Delta smelt protection and ecosystem restoration should target improving thermal conditions and establishing thermal refuges in the midafternoon periods.

Next steps: C. Lee and team continues to partner with the Metropolitan Water District to evaluate thermal suitability for endangered and nonnative fish to enhance habitat conditions.

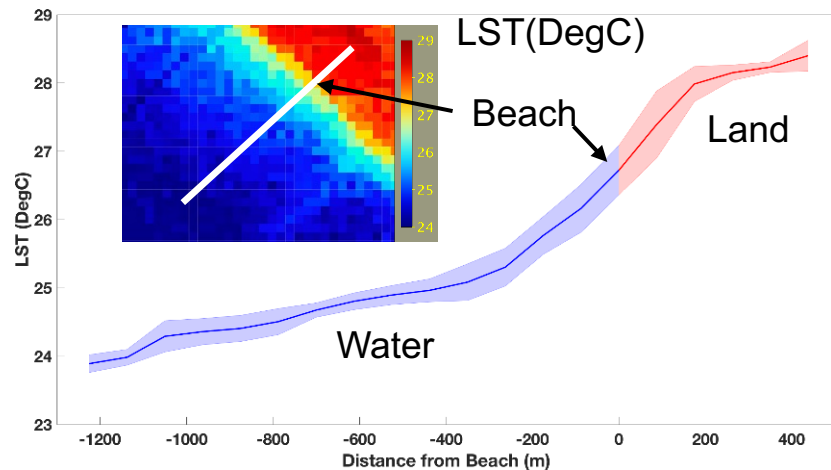


Using ECOSTRESS to measure surface temperature at the shoreline and over water

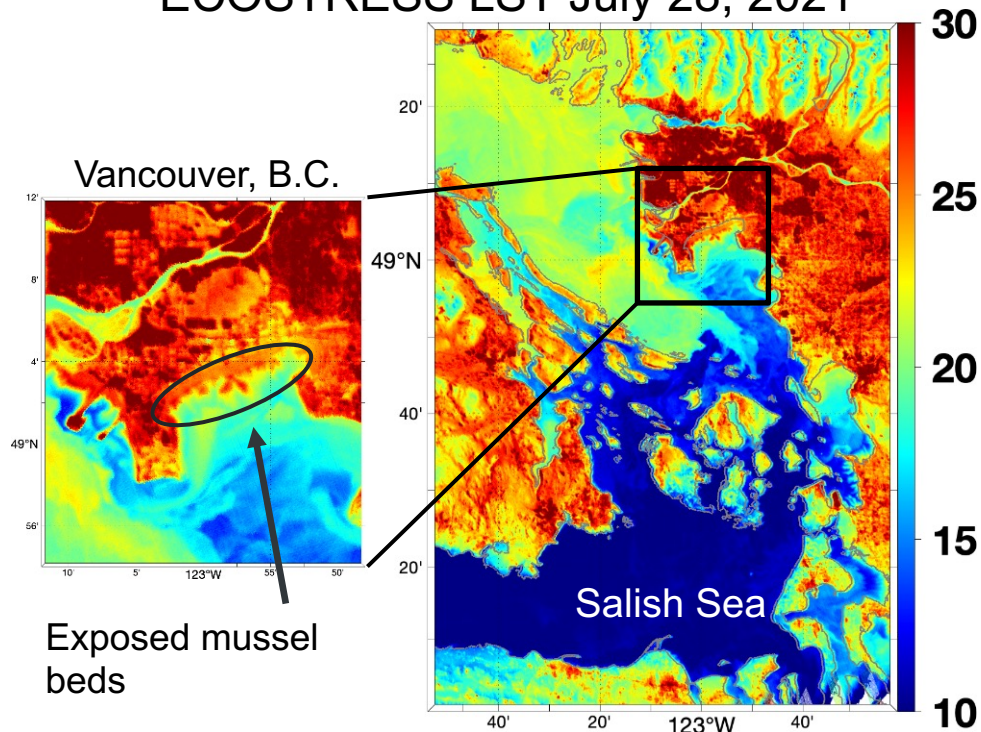
(PI: D. Otis - University of South Florida, College of Marine Science)

Project goals:

- Utilize the high spatial resolution of ECOSTRESS to measure surface temperature at the land-water interface, which is not possible with sensors like MODIS.
- Shoreline habitats are rich in biodiversity. We characterize them in terms of temperature using transects called temperature profiles.

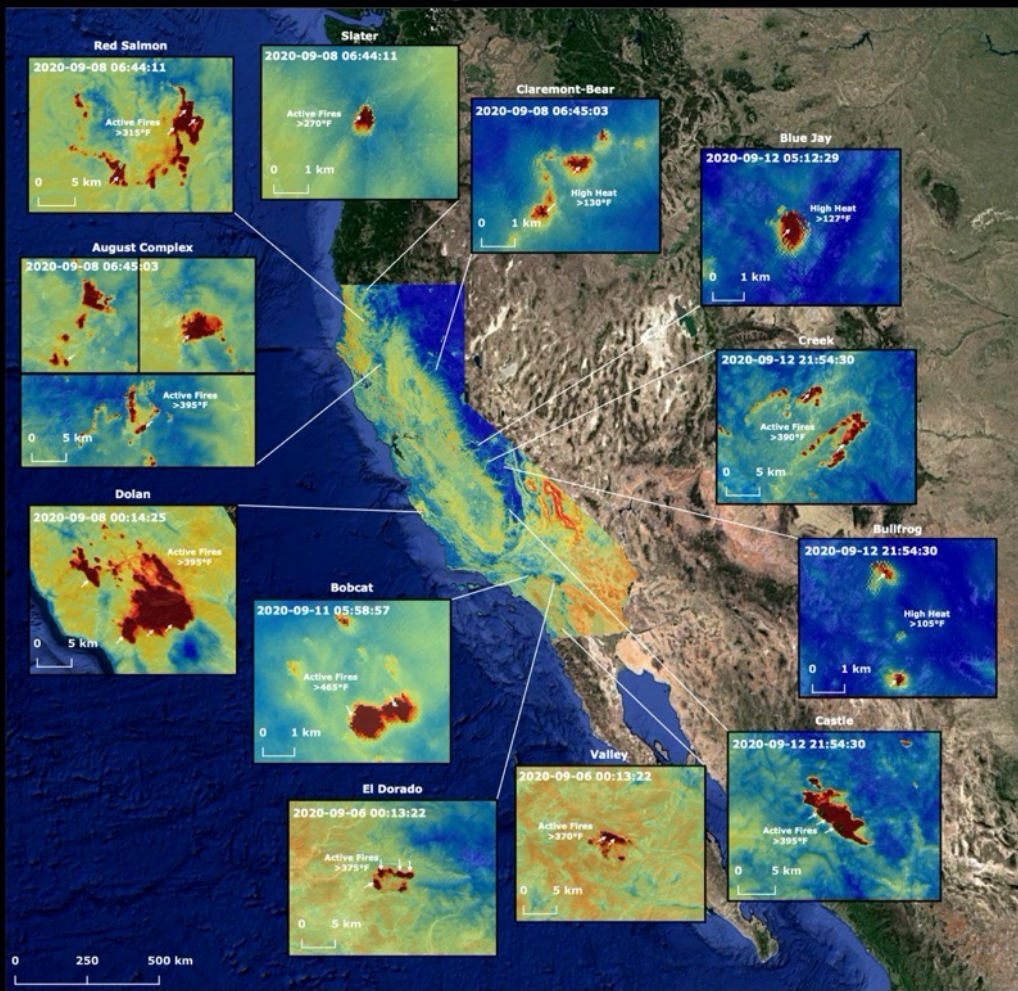


ECOSTRESS LST July 28, 2021



In late June and July, beaches here experienced elevated surface temperatures and widespread mortality of mussel beds.

ECOSTRESS Images California Wildfires

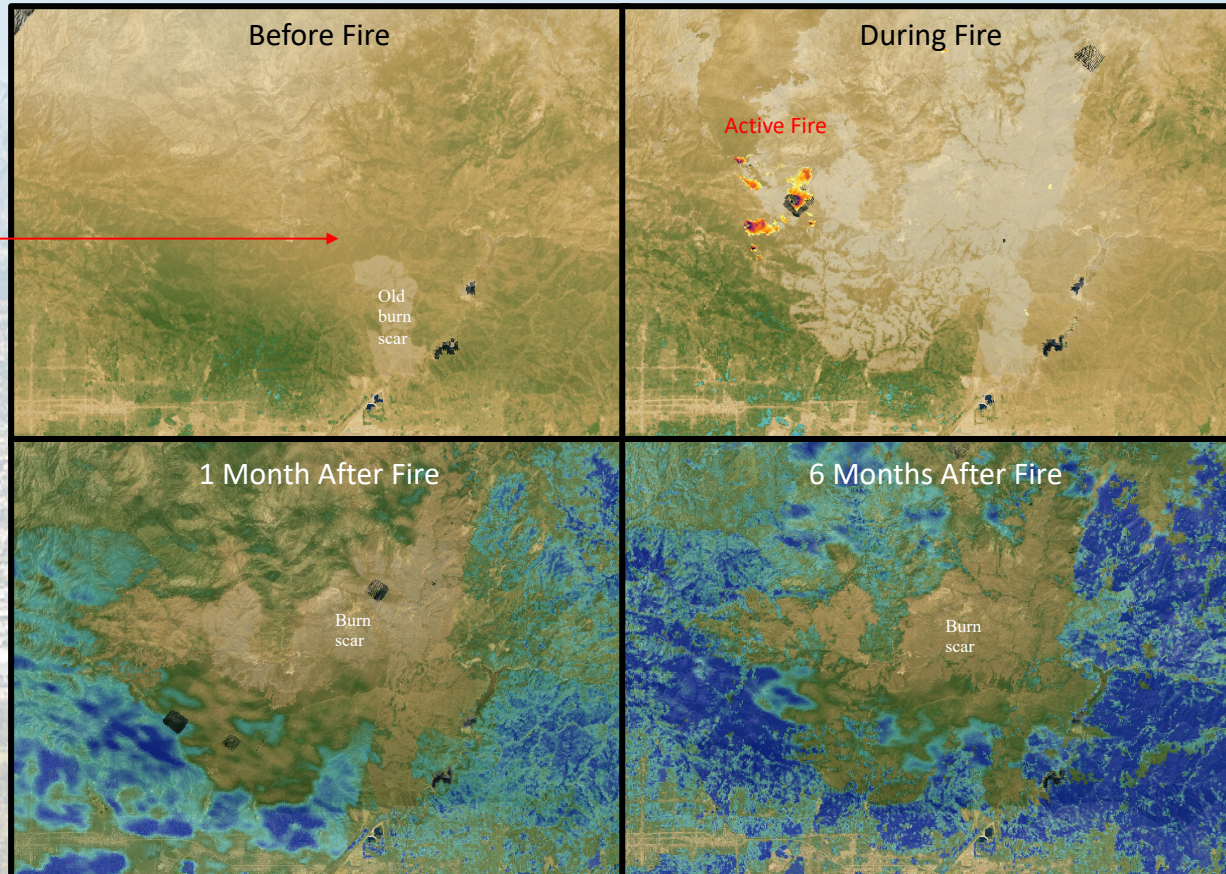


Wildfires



Bobcat Fire, California, September 2020

Fire began in stressed vegetation in the mountains, and grew enough momentum to continue to burn through healthier vegetation in the foothills



35 C 75 C
Land Surface Temperature

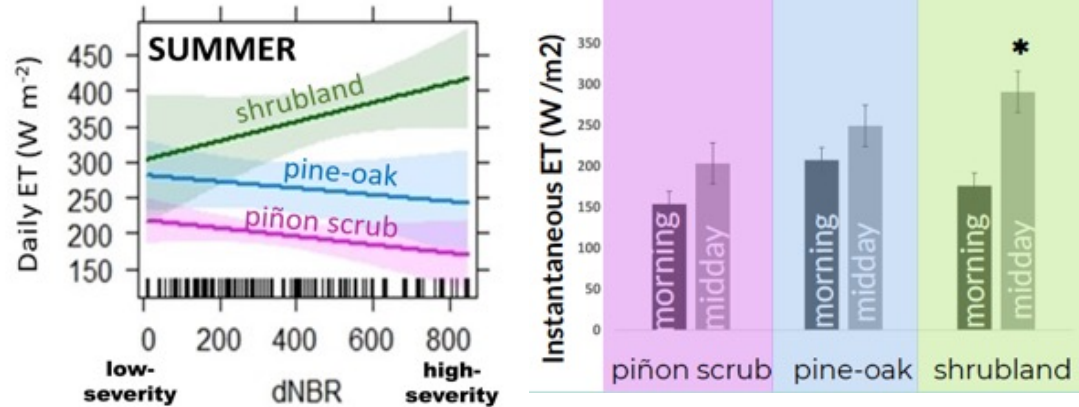
Low stress High stress
Evaporative Stress Index

0 2.5 5 km

nasa.gov

Post-Fire severity influences post-fire evapotranspiration (PI: H. Poulos)

- Fire severity modulates post-fire evapotranspiration
- Post-fire shrublands have high summer and midday ET relative to other vegetation types
- Post-fire ET is a metric of vegetation recovery and water cycling, critical for guiding forest management and restoration activities



[Link to article: Remote Sensing in Ecology and Conservation.](#)

[2021. doi: 10.1002/rse2.210](#)

HyTES



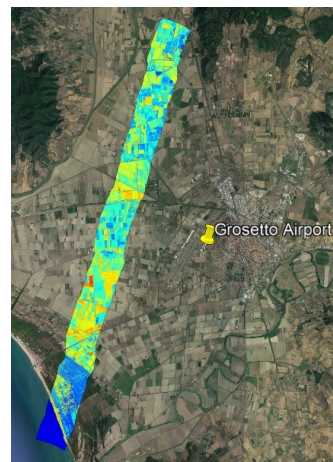
Hyperspectral Thermal Emission Spectrometer (HyTES) –2021 European Campaigns

- Joint European campaign Summer 2021:
 - LIASE (Spain July 8-12)
 - UK-TIR (England June 17-July 5)
 - NORDIC-Methane (Scandinavia August 16-September 12)
- HyTES is installed on the British Antarctic Survey Twin Otter.
- Work undertaken through Space Act Agreement (SAA) between Kings College London (KCL) and NASA OIIR.
- UK will provide several additional sensors: Fenix 1K VIS to SWIR, Specim IBIS SIF, Specim Owl LWIR, Hypercam LWIR & Methane specific detectors.

Instrument Characteristic	HyTES
Mass (Scanhead) ¹	12kg
Power	400W
Volume	1m x 0.5m (Cylinder)
Number of pixels x track	512
Number of bands	256
Spectral Range	7.5-12 μ m
Frame speed	35 or 22 fps
Integration time (1 scanline)	28 or 45 ms
Total Field of View	50 degrees
Calibration (preflight)	Full aperture blackbody
Detector Temperature	40K
Spectrometer Temperature	100K
Slit Length and Width	20 mm x 39 μ m
IFOV	1.7066
Pixel Size/Swath at 2000 m flight altitude ²	3.41m/1868.3 3m
Pixel Size/Swath at 20,000 m flight altitude ²	34.13m/18683 .31m



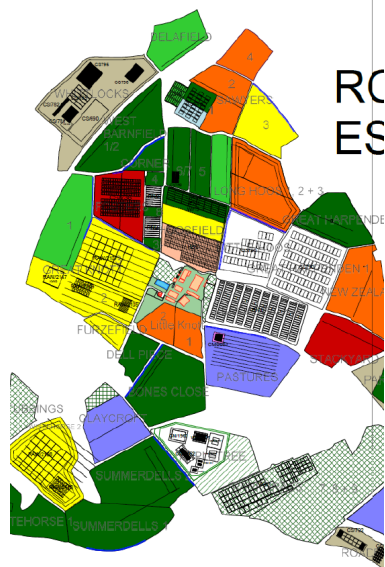
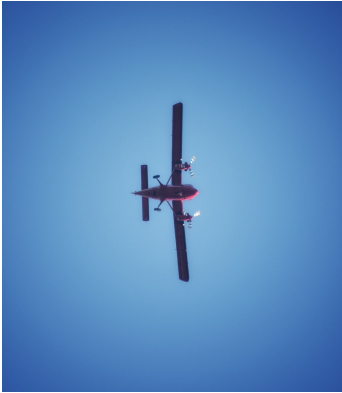
British Antarctic Survey Twin Otter



HyTES imagery acquired near Grosseto, Italy
Acquired in 2019

2021-07-20
11:25:22

Rothamsted
Research station
showing the
experimental fields
and JPL
measurements in
barley field with
BAS Twin Otter
overhead



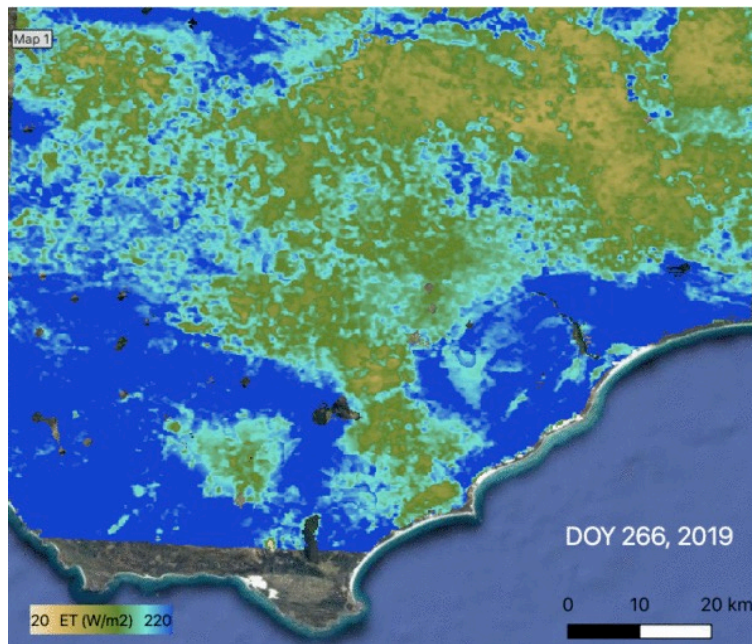
1ST WHEAT	W / OATS
2ND WHEAT	S / OATS
3RD WHEAT	PASTURES
SPRING WHEAT	W / BEANS
WOSR	S / BEANS
SOSR	CAMELINA
W / BARLEY	LINSEED
S / BARLEY	

Stephen Goward
Mark Gardner
NICK Chichester-Miles
Tim Hall

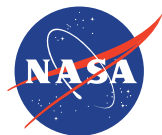
Martin Gardner
Paul Lutterby
Rob Copley

ECOSTRESS for Biodiversity and Ecology

- Readily available LST and ET data in GeoTIFF format through AppEEARs
- High resolution spatial (~70 m) and temporal (1-5 day) data
- For the monitoring of vegetation response to ecosystem dynamics



Evapotranspiration
over the Southern
portion of the Cape
Floristic Region



Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov

Image credits:

Kerry Cawse-Nicholson

Gregory Halverson

Glynn Hulley

Christine Lee

Joalda Morancy

Joshua Fisher

Jonathan Vellanoweth

Dan Otis